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Technical Note N-458

EMPLACEMENT OF THE FIRST SUBMERSIBLE TEST UNIT ON THE SEA FLOOR - ONE MILE DEEP

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U. S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

EMPLACEMENT OF THE FIRST SUBMERSIBLE TEST UNIT ON THE SEA FLOOR - ONE MILE DEEP

Task No. Y-F015-01-001(c)

by

Ronald E. Jones

ABSTRACT

The techniques and systems for construction in deep ocean areas must be developed to support the new concepts of Naval warfare. A complete understanding of the behavior of materials in the deep ocean environment is an important part of this development.

A series of deep ocean materials exposures has been planned, the first of which is described herein.

The criteria for a suitable study site, the locating techniques used for establishing its accurate position and the installation of a 3-1/2 ton Submersible Test Unit (STU) containing engineering materials specimens (metallic and nonmetallic) at the selected site are described. The behavior of plastic ropes under load and special procedures dictated by their use are discussed.

The precautions taken to assure retrieval of the STU are presented in detail.

The collection of environmental data is described.

CONTENTS

INTRODUCTION

A widespread and increasing interest in the deep ocean (defined as having a water depth exceeding 2000-feet) as an operating environment has created a demand for data about the chemical, biological and physical characteristics of the water, the sea floor and the underlying sediments and formations.

The effect of these characteristics on the various materials that may be used for construction is of particular interest to engineers and designers who may be called upon to build and maintain structures in the deep ocean.

NCEL has therefore, as part of Task Y-F015-01-001, Structures in the Deep Ocean, initiated a study whereby construction materials (conventional and unconventional) will be exposed to the deep ocean environment at various depths and for various time periods.

The first such exposure was commenced with the emplacement of the first Submersible Test Unit (STU)[1] (Figure 1) in March 1962 for a period of six months at a depth of 5300 feet. This unit provides for exposure of specimens below, within and above the sediment-water interface.

This report presents information about (a) the criteria used for choice of site, (b) the emplacement and retrieval complex, and (c) the instrumentation integrated into the system. A detailed description of the equipment and procedures used in emplacement of the STU is presented.

CHOICE OF TEST SITE

Choice of a site (Figure 2) was based upon many factors such as environment, accessibility, relocatability, and navigational hazards (surface and subsurface).

The site chosen is located approximately at the intersection of a line drawn due south from Point Arguello and a line drawn due west from Long Beach, California. The site is suitable because of the following factors.

1. The sea floor slopes very gently; the sediments are not newly deposited; there is no evidence of severe currents at the sea floor; it is not an enclosed basin (such as the Santa Cruz Basin); it appears to be typical of the Continental Slope off the Southern California Coast.

2. Distance from the nearest land is about 20 miles; distance from NCEL is about 75 miles; sea conditions for surface recovery craft are fairly good during most of the year.

3. It is within sight of permanent survey markers located on Santa Rosa and on San Miguel Islands; distances from the survey points are within the operational limits of capability of Tellurometer (electronic distance measuring device) and conventional surveying equipment.

4. It is outside surface and subsurface shipping lanes.

SYSTEM DESIGN CHARACTERISTICS

The STU is essentially a tower 14 feet tall to which are attached racks of materials specimens. It is supported on a base 12 feet square which also provides for the accommodation of specimens. A core barrel is attached to the STU for the purpose of recovering a core from the sediment upon which the STU rests.

The following criteria for the STU system were adopted: the integrity of the whole system has to be maintained throughout the exposure period; the STU must remain essentially upright; the STU must not settle excessively (more than 1 or 2 feet) in the sediments; the STU must emit identifying signals to assist in its retrieval; the system must remain secure from hostile interference, storms, and accidental damage; the STU must be recoverable.

System Integrity

The design of the system had to provide for good probability of retrieval of the STU. Therefore, all components essential to emplacement and retrieval of the STU were considered for their ability to withstand exposure to the deep marine environment as well as to perform their normal functions. Nylon and polypropylene ropes were chosen for all load bearing lines because of their excellent resistance to bacteria, fungi and other sea life, and because they are relatively inert to the chemical action of sea water. Components in direct contact with the ropes, such as thimbles, were made of stainless steel (316). The remaining components

were made of mild steel and of such physical dimensions that it is believed corrosion is unlikely to cause damage of significant proportions during the exposure period.

STU Attitude

In order to minimize the possibility of overturning, the STU was provided with a large base and designed to have a low center of gravity. A pinger, the rate of which varies with its angle of deviation from the vertical was attached to the STU for monitoring attitude during placement.

Prevention of Excessive Settlement

Knowledge about the bearing capacity of the sediments was of vital importance to the success of the experiment. Based on data concerning the bearing capacity of the sediments of the Southern California Continental Slopes as given by Moore, 1961[2], a value of 50-lbs per square foot was used. A sheet steel skirt and other steel plates were attached by means of magnesium bolts to the base of the STU in order to reduce bearing stress on the sediments to this amount. The skirt configuration reduces the possibility of erosion due to water motion. This sheet steel will be left at the bottom upon recovery of the STU since the magnesium bolts undergo rapid electrochemical deterioration when in contact with steel in sea water. An example of electrochemical attack on one of the magnesium bolts is seen in Figure 3 where the nut, washers and plates are steel and the result of 24 hours immersion in sea water in the laboratory is demonstrated by the corroded magnesium bolt. Complete disintegration of the bolt took place in 72 hours. Shear and consolidation tests on sediment collected near the STU site during the emplacement operation indicated a much higher bearing capacity than was originally anticipated. The bearing strength of the sediments is estimated to be not less than 250 lbs per sq ft.

Sound Emitters

To facilitate retrieval operations and to serve as a guide to the STU location a pinger was placed on the STU and a second one was located in its retrieval system. By means of a hydrophone, the sounds emitted can be identified and traced to their source from a maximum distance of about two miles. Life of the pingers is estimated to be about one year.

Security

The possibility of hostile interference by foreign interests or vandalism by domestic fishermen and others has been considered. Leaving no surface indicator to mark the location of the STU will, it is hoped, abrogate such a possibility. Figure 4, a schematic of the STU complex, shows the retrieval system with the upper buoy located at a minimum depth of 200-feet. Such an arrangement not only provides protection from accidental damage by ships or by storm disturbances but also provides a high degree of security from unauthorized interference.

Retrieval

Althernate methods of recovery were provided to assure good probability of retrieval of the STU.

The complex presented in Figure 4 contains a primary retrieval system backed-up by two alternates. The primary system makes use of an acoustically actuated release (a proprietary device) located as shown in Figure 4. It consists of a hydrophone, a protective case containing an amplifier and decoder, and an explosive link. The link can be triggered by exploding a series of three blasting caps suspended a short distance below the surface of the ocean within about 1/2 mile of the device. A discreet time interval between explosions provides the code needed to effect triggering. Incorrect timing (or noise) can jam the system; after a period of about 1 minute it recovers and can respond to the proper signal. Upon release, the "life-line" and buoys will ascend to the surface. A smoke flare, activated by surfacing, will indicate the position. The STU can then be retrieved.

In the event that the primary retrieval system fails, a temporary mooring with a surface buoy will be installed near the submerged buoy cluster. A weighted bight of rope (about 1500-feet long) will then be suspended between the vessel and the temporary buoy and the vessel will circle the buoy in an attempt to snag the upper buoy cluster as the suspended rope is towed by. Thus the "life-line" with its sinker and buoy may be lifted to the surface. The acoustic release must be disarmed on recovery. This involves breaking an external connection at the device when it reaches the sea surface.

Failure of the secondary system - possible if the upper buoy cluster is damaged, breaks loose, or sinks - necessitates the use of a third system - a suspended grapnel to snag the 6000-foot inverted catenary of the polypropylene lowering line. This also necessitates disarming the acoustic release when it is brought to the surface.

General

The STU submerged weighs about 6000-lbs. The most critical load conditions were expected to occur during the first 500-feet of the lowering operations when large transient forces were induced by movements of the ship against the drag resistance of the STU. For this reason 500-feet of nylon line (4 inch circumference - ultimate tensile strength 40,000 lbs) was attached to the STU. After lowering the STU 500 feet the relationship between ship motion and line length became more favorable and transient loads were reduced. A forty foot length of one-inch chain connected the opposite end of the nylon to the end of the 6000-ft polypropylene line and acted as a sinker. The polypropylene rope (Sp.G = 0.9, 1-inch diameter, 3 strand) is buoyant and has an ultimate tensile strength of 14,000 lbs. This buoyant line provides the inverted catenary needed for the third method of retrieval (Figure 4). The "life-line" shown in Figure 4 is also polypropylene and connects the upper and lower buoy clusters. Below the lower cluster are the current meter (80 lbs), the acoustic release (20 lbs), and the concrete sinker (1000 lbs). Each buoy cluster (consisting of three gasoline-filled 55 gallon neoprene containers) provided a net buoyancy of about 280-lbs. Thus the 4 foot square 8 inch thick concrete sinker exerts a load of about 500 lbs on the sea floor or less than 35 lbs per square foot. The line was attached to a lifting eye on the side of the sinker to assist in freeing it from the bottom in the event of failure of the primary retrieval system.

SPECIAL FEATURES

In Situ Current Measurement

A record of the horizontal water motion at the STU site will be obtained from the self-contained recording current meter (Woods Hole Type) located as shown in Figure 4. The instrument (Figure 5) is designed to record current speed and direction for 1 minute of each half hour during 6 months (alternate programming is possible). It senses speed by means of a Savonius Rotor and direction by means of a vane and magnetic compass. The instrument is designed for suspension in a line, being provided with upper and lower U-bolt attachments, and was located about 14-feet above the sea floor between the lower buoy cluster and the acoustic release (Figure 6). The data is collected on photographic film and at the end of the six-month exposure period will be processed and used to partially evaluate the environment in which the STU is located.

Cooperative Study

Data about the earth's electric potential is required by Scripps Institution of Oceanography in support of an ONR sponsored study. Therefore, the STU carried an instrument package to which is attached a half-

mile long cable and two electrodes. Some slight deviations in procedure - mainly limiting the lowering rate of the STU - were adopted to allow the electrodes to be carried to the sea floor. A two-mile-long tag line was used to keep the electrode cable straight while the STU placement was completed. About 50 lbs tension was maintained in the tag line using a small outboard motor boat launched from a PT boat.

INSTALLATION PROCEDURE

Weather predictions for the week commencing 26 March 1962 were favorable. Accordingly, the NCEL work vessel, YFU-48 (Figure 7) was temporarily based at Santa Rosa Island. Some of the participating personnel were housed ashore because of the limited shipboard accommodations. Three separate operations were planned, the first to place the mooring (Figure 8), the second to install the STU and the third to retrieve the mooring.

The general location of the STU site, chosen on the basis of information available from C.&G.S. charts, was checked for depth using a precision depth recorder aboard the USNS RICHFIELD (Figure 9). When a satisfactory position with regard to depth and bottom slope was found, surveyors at Station Farrell on Santa Rosa Island and Station San Miguel 4 on San Miguel Island computed from observations the position for the mooring. Conventional surveying equipment and Tellurometers were used to accurately guide the ship to the location chosen. The ship then dropped a dye-marker and moved off allowing the YFU to occupy the position and lower the anchor for the temporary mooring. During the time taken (about 40 minutes) for the lowering operation the YFU drifted. The resulting location was in shallower water than anticipated being 5300-feet deep rather than the desired depth of 6000-feet. Surveyors established the new location after the surface buoy had been connected (Figure 10). The distance from submarine transit lane Sierra Venus was carefully checked to avoid any hazard to submerged craft.

On the second day, loaded with the STU, the YFU returned to the site and moored to the temporary mooring buoy. Sea state was about three (waves 1-1/2 feet to 4 feet high). The nylon mooring line (4 inch circumference, ult. tens. strength 40,000 lbs) was paid out from the stern of the YFU (Figure 11) as the vessel moved away. The line was stopped off at approximately 5000-feet and a tension of about 3000-lbs was maintained by means of ship's power.

With the position of the YFU controlled by the length of line and the heading, preparations were made to lower the STU. The electrode line was passed over (Figure 12) from the PT boat and it was secured to the

recorder on the STU. After preliminary checks the PT boat moved away paying out the electrode cable. A final electrical check was made, the recorder was secured, the STU was lifted, placed over the side of the YFU (Figure 13) and lowered into the water (Figure 14) until the load was supported by the nylon lowering line passing over the starboard bow roller. The surveyors recorded the position of the YFU at that time. The cranehook was disengaged and the load supported on a 500-ft long 1-5/16 in. diameter nylon line. Figures 15 and 16 illustrate the sequence of operations. As the STU was lowered, ship motion and the drag of the STU through the water caused changes in the line load which were measured by means of strain gages at the bow roller. The load applied by the 6000-lb STU to the line was varying between about 4000 and 8500-lbs. However a severe ship movement produced a load change from 2500 to 11,000-lbs when the STU was about 200-feet down. By the time the STU was 500-feet down load maximums did not exceed 8000-lbs. A 40 foot length of 1 inch chain (to act as a sinker) was attached to the end of the nylon. The chain was paid out, followed by 6000-feet of 1-inch diameter polypropylene rope. A lowering rate of about 100-feet per minute was maintained during the remainder of the STU descent.

When the STU reached the sea floor (indicated by the reduction in load as measured by strain gages at the bow roller) its attitude was checked and found to be about 6 degrees from vertical. This was indicated by the output rate of the pinger attached to the STU which varied with deviation from the vertical. Since the angle was not excessive, no attempt was made to reposition the STU.

The YFU slowly hauled itself back 300 feet by means of nylon mooring line while the polypropylene line was paid out 550 feet to allow the chain to be placed on the bottom. The concrete sinker, 10-feet of polypropylene line, acoustic release, current meter, lower buoy cluster and "life-line" were then attached as shown in Figure 6. The YFU then hauled itself back 3000-feet as the "life-line" was paid out until the sinker reached the sea floor (Figure 16). At this time sea conditions were rapidly approaching a state of 5 (8-13 ft high waves) causing considerable difficulty in handling loads and assembling components.

After winding in 200-feet of the "life-line", the upper buoy cluster was attached to it. The cluster was then lowered over the side and a smoke flare attached to the line 100-feet above the buoys. The assembly was then lowered until the sinker reached the sea floor; the line was then released. In its final position the upper buoy cluster was 200-ft below the sea surface

When the YFU was released from the mooring line, the sea state was about 6+ and the vessel was returned to its anchorage at Santa Rosa Island.

ENVIRONMENTAL DATA COLLECTION

During the STU emplacement operation, use was made of the oceanographic winch and boom to lower the deep sea camera and scoop sampler in order to photograph and obtain samples of the bottom sediments. The gravity corer shown in Figure 17 (loaned by NEL, San Diego) was furnished with a retaining trap at the lower end and a ball valve at the top. It contained a rigid plastic tubular liner to permit removal of the entire unbroken core (Figure 18). Cores were also obtained to study the bacteria population of the sediment. Samples for biological study were also scooped from the sea floor using the sampling device shown in Figure 19. The tubes with compressed rubber bulbs attached (Zobel samplers) were used to obtain water samples at the sediment-water interface for bacteriological study. The Frautschy bottles shown in Figure 19 were used to obtain samples of water near the sea floor for pH, oxygen and salinity determination to define the environment. Details of analysis of the various samples will be reported separately by others.

Sea floor photographs were obtained using the NEL Mk V camera (Figure 20) over seventy useful frames were obtained. Two examples are presented in Figures 21 and 22.

RESULTS

The Submersible Test Unit carrying 1318 samples of 301 different materials was successfully placed on the sea floor at a depth of 5300 feet. Its column is only 6 degrees off vertical.

The pingers attached to the STU and its retrieval complex were emitting identifying signals at the time of leaving the site. The rigging of the retrieval system was installed with some minor damage as a result of rough water.

Samples of water and sediments were successfully collected for chemical, mechanical and biological analyses.

Photographs of the sea floor were obtained which show evidence of considerable biological activity. The absence of sand ripples and the rough sediment surface suggests the absence of steady as well as oscillatory water movements of any significance. Also sediment thrown into suspension by contact of the camera with the sea floor indicates no significant water currents. A sequence of frames containing a large fish drifting about 6-feet above the bottom was interpreted by an NEL deep-sea photographer to indicate a current speed of the order of 0.03 knots.

SUMMARY OF IMPORTANT OBSERVATIONS

Engineering analysis of the bottom sediment samples indicates that the STU is located on a satisfactory foundation. The site appears to be typical of the Southern California continental slope.

Plastic lines can be successfully used to lower relatively heavy loads (3 tons submerged) to the sea floor at depths of at least 5300-feet. Their light weight (or buoyant quality in the case of polypropylene) allows the bottom to be sensed by monitoring tension.

The highly elastic quality of plastic lines reduces the problem of shock loading associated with winch operation and ship motion.

Sampling devices (sediment scoop, sediment corer, water sampler) and a deep sea camera can be successfully operated down to depths of at least 5300-feet.

The YFU work vessel cannot be operated reliably in a sea state exceeding 3. The vessel does not contain either adequate or sufficient accommodations for personnel to conduct this type of operation. Its low speed (about 6 knots requires excessive travel time for operations far from shore.

ACKNOWLEDGMENTS

The assistance of many NCEL personnel who contributed materially to the success of the operation is sincerely appreciated. Grateful acknowledgment is made to Mr. Carl Shipek of the Naval Electronics Lab., San Diego, who photographed the sea floor at the STU site and the Marine Air Group 36 for helicopter support. The assistance of surveyors of the Public Works Department directed by Mr. Robert Littell and personnel of the Surface Craft Division of the Naval Air Station, Point Mugu, as well as personnel of the Pacific Missile Range Ship RICHFIELD is gratefully acknowledged. The efforts to assist in accommodation of personnel on Santa Rosa Island by the 669th AC&W Squadron, U.S.A.F. are appreciated.

REFERENCES

1. U. S. Naval Civil Engineering Laboratory. Technical Note N-446, Effects of the Deep Ocean Environment on Materials, by K. O. Gray. Port Hueneme, 30 July 1962

2. U. S. Navy Electronics Laboratory. Technical Memorandum TM-458, Tables of Bearing Strength and Other Physical Properties of Some Shallow and Deep-Sea Sediments from the North Pacific, by D. G. Moore. San Diego, 7 February 1961.

APPENDIX I

Ship Equipment

The work vessel used for the STU emplacement was a YFU as shown in Figure 7. This is a converted LCT landing craft 119 ft long and 34 ft wide manned by a civilian crew. It contains accommodations for 12 persons in bunks and there is additional space for 5 cots. Maximum speed of the vessel is about 7 knots in calm seas. Assistance in location of the site was furnished by the PMR vessel USNS RICHFIELD (Figure 9) as a stable survey platform (the YFU was found to lack sufficient stability) and a PT boat (Figure 12) to support the cooperative task for Scripps Institution of Oceanography.

In order to place loads over the side of the YFU, a 20-ton truck crane with a 55-foot boom was located approximately at the ship's center (Figure 7). This position was such that the crane could rotate through more than 270 degrees and could reach either bow or stern.

A two-drum winch was located near the bow on the starboard side and a roller on the port bow was so placed that a cable from this winch was aligned with it. This winch was required for placement of the temporary mooring. Each drum of the winch held 3600 feet of 1-inch diameter wire rope.

A two-drum winch was also located in the cargo area near the stern and its gypsy head was used for the vessel to haul itself back on the nylon mooring line. The nylon line was stored at low tension on the drums. A roller on the stern was provided for the line (Figure 11). Unlike polypropylene it was found that nylon under tension could be pulled over a gypsy head without damage to the line.

A single drum torque-converter winch with a gypsy head was located at the port side near the bow. Modifications were made in order to handle polypropylene (or other plastic lines) as shown in Figures 23 and 24 where 1-inch diameter polypropylene line was reeved over a grooved capstan and idler. An air-driven storage drum was located nearby fc winding line at low tension (Figure 23).

A winch normally used for anchoring the YFU in shallow water when beaching was located on the raised portion of the port quarter. This winch was used with a king-post and jib for oceanographic casts (Figure 25). The winch drum carried 8000-feet of 1/4-inch diameter wire rope.

Line load could be constantly monitored at the starboard bow roller by means of strain gages attached to the roller support. Line speed could also be monitored. Line load was constantly monitored at the

oceanographic winch by measuring load using a strain gage bridge bonded to a tension link in order to enable the bottom to be sensed when lowering the corer (Figure 17), camera (Figures 20 and 25), Frautschy bottles and mud sampler (Figure 19).

APPENDIX II

Tests on Polypropylene Ropes

Two short lengths (5-feet) of 1-inch diameter polypropylene rope were tested to destruction in a tension test. Both tests exceeded the manufacturers specified breaking strength of 13,600 lbs. When loaded to 50 per cent of the breaking strength, an increase in length of about 12 per cent was measured. Failures occurred with a visible flash without warning and the ends of the plastic fibres at the place of failure appeared to be fused.

Efforts were made to wind 1-inch diameter polypropylene rope on a conventional winch while supporting a 6000-lb load. The rope buried itself in preceeding layers and showed signs of burning (plastic fusing). The same rope when wound over a cat-head under load could not be slipped across the drum without burning.

According to Dr. Richardson (by letter) of Woods Hole Oceanographic Institution, polypropylene and other plastic lines when wound on winch drums under great tension exert forces sometimes large enough to crush the drum and also weaken the lines.

The grooved rollers shown in Figures 23 and 24 were designed to develop sufficient friction between rope and groove to prevent slippage when winding and thus eliminate burning. The roller in the foreground was driven by the winch and replaced the cat-head. The other roller is an idler. The low-tension end of the rope was led onto an air driven storage spool (Figure 23) (capacity: 12,000-feet). Tests of this system were conducted by dragging a mule (heavy towing vehicle) across a concrete pavement. A pull of 7000-lbs (measured on a Dillon dynamometer) was obtained with no rope slippage and a slack line at the spool end.

APPENDIX III

Tests of Components

Several components of the retrieval system were tested prior to emplacement of the STU. Specifically, laboratory and sea tests were conducted on the current meter, acoustic release, and pingers.

The current meter was checked for response to motion of the rotor and vane in the manner suggested in the instruction manual. The performance of the timing and programming unit was checked by visual observation. The assembled unit was subjected to immersion in the ocean down to 6000 feet and its water-tight integrity was verified.

The acoustic release was bench-tested using a photo-flashbulb in place of the explosive link and lightly tapping the hydrophone according to the release code to check its operation. Random time intervals between taps were used to check its discrimination against improper signals. In a series of deep submergence tests using explosive grenades to initiate the explosive release the grenades were rejected as faulty. The release was found to be extremely sensitive to mechanical vibration. After correction, bench tests indicated proper performance.

Pingers were bench tested for reliability over short periods and the attitude sensor was checked with the STU-mounted pinger to determine its ability totransmit accurate data concerning the attitude of the STU with respect to vertical. Sea tests at 6000 feet submergence indicated no leakage problem and showed that the signals could be heard with a hydrophone. A potentiometer type attitude sensor using a two-conductor line to carry signals was used to check the performance of the pinger attitude sensor.

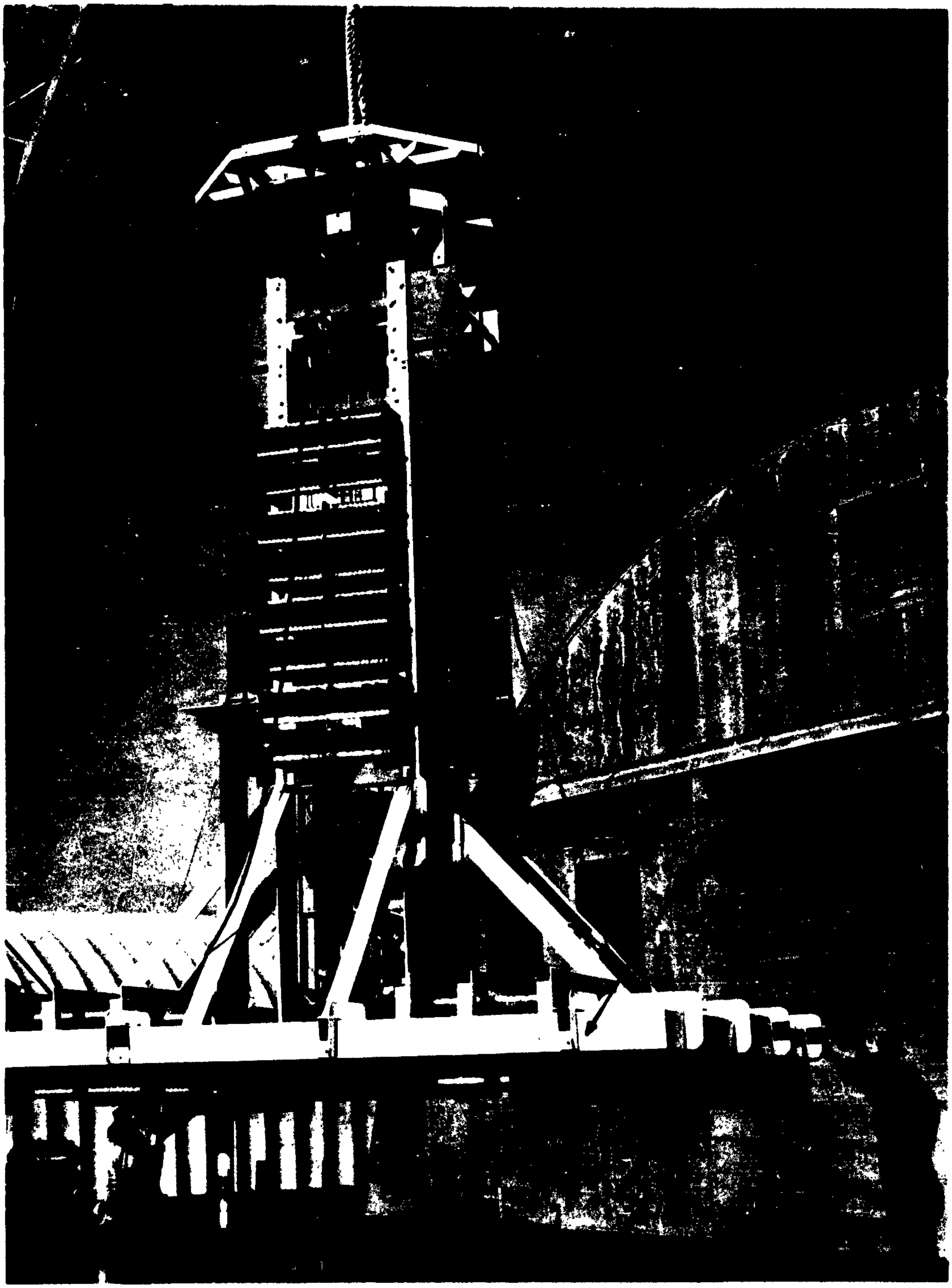

Figure 1. STU with specimens ready for loading on YFU.

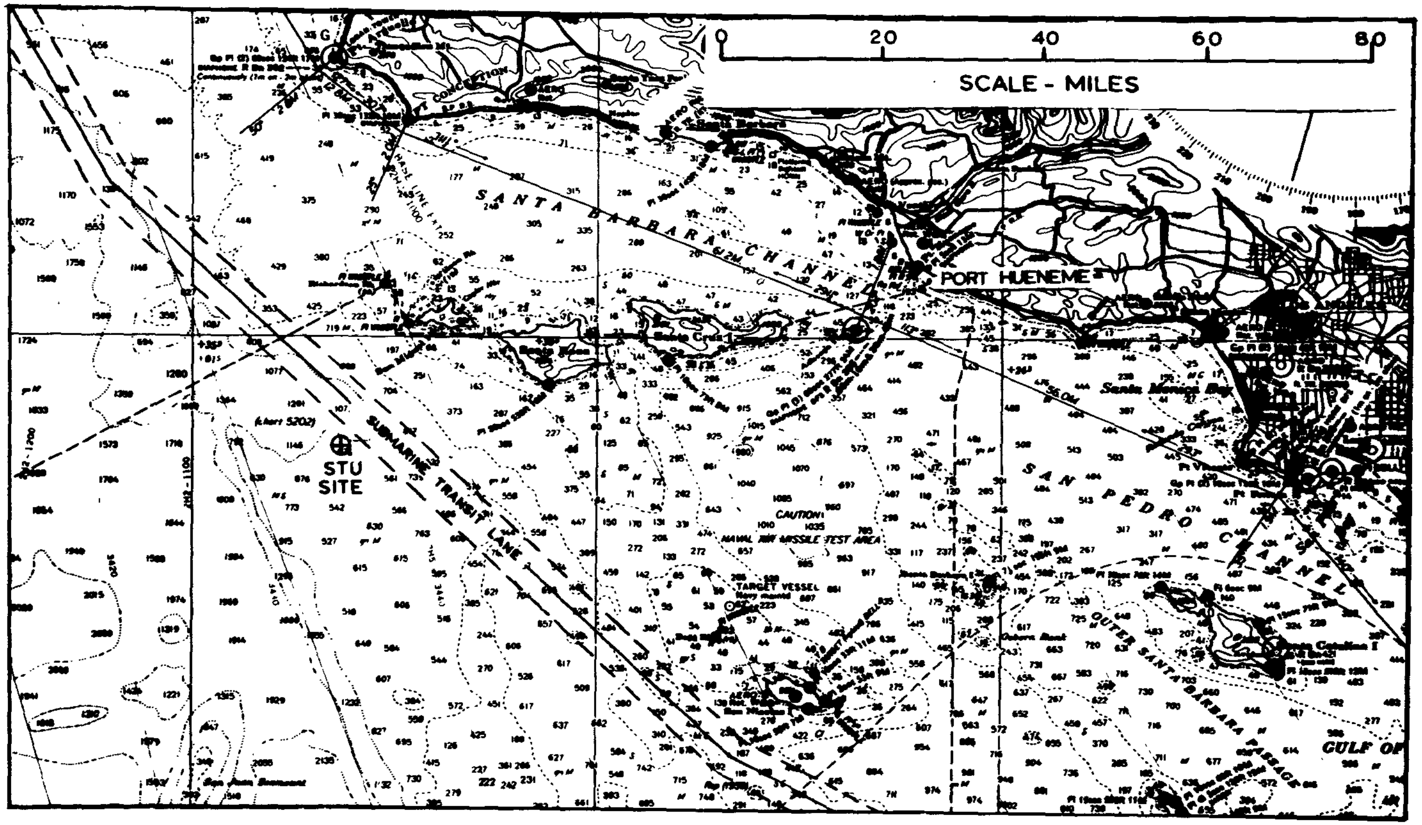

Figure 2. Test site off Southern California coast.

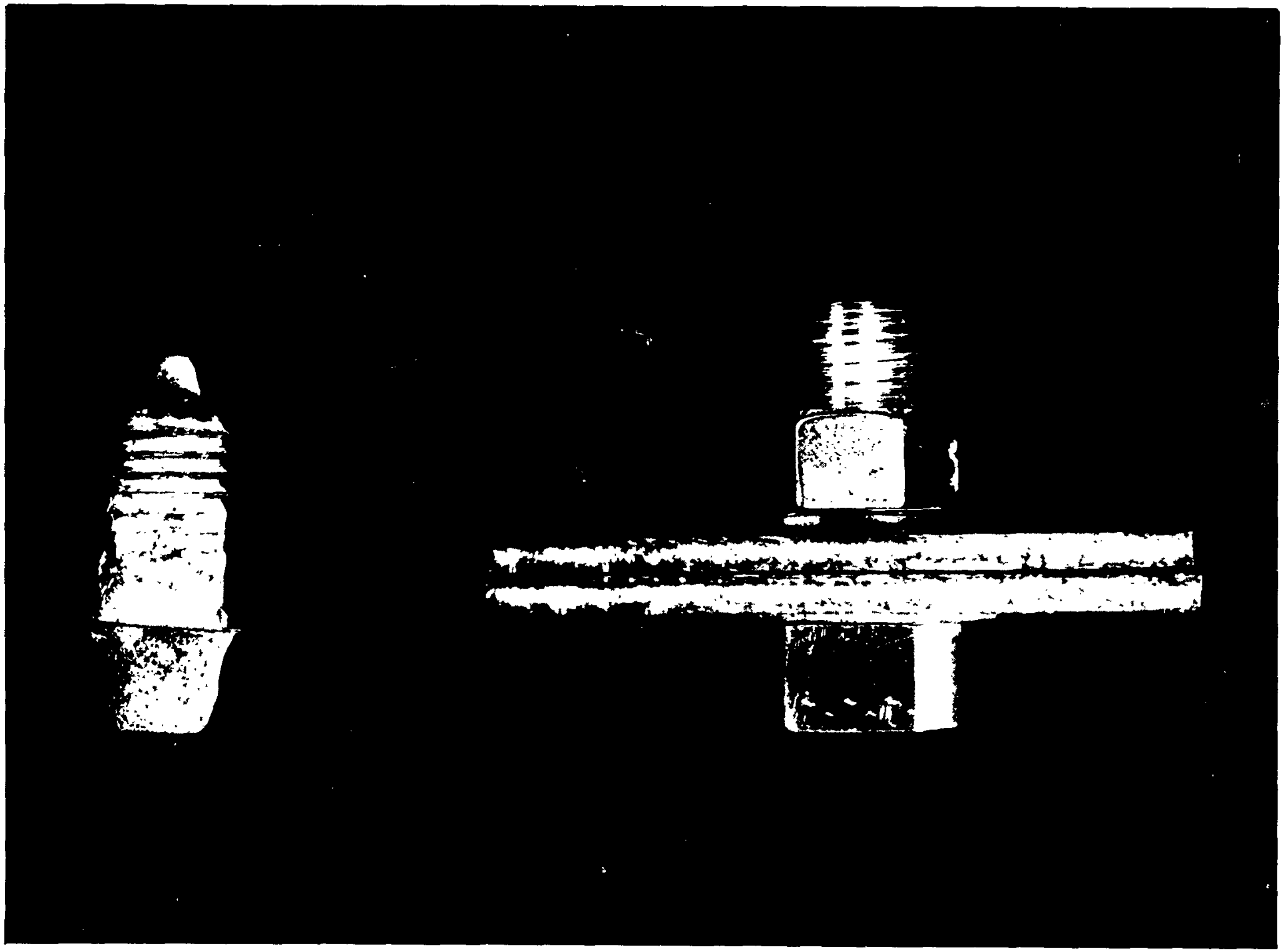

Figure 3. Corroded Magnesium bolt (left) after 24 hours exposure in sea water. Original assembly of Magnesium bolt, steel plates, steel washers, and steel nut are shown on right.

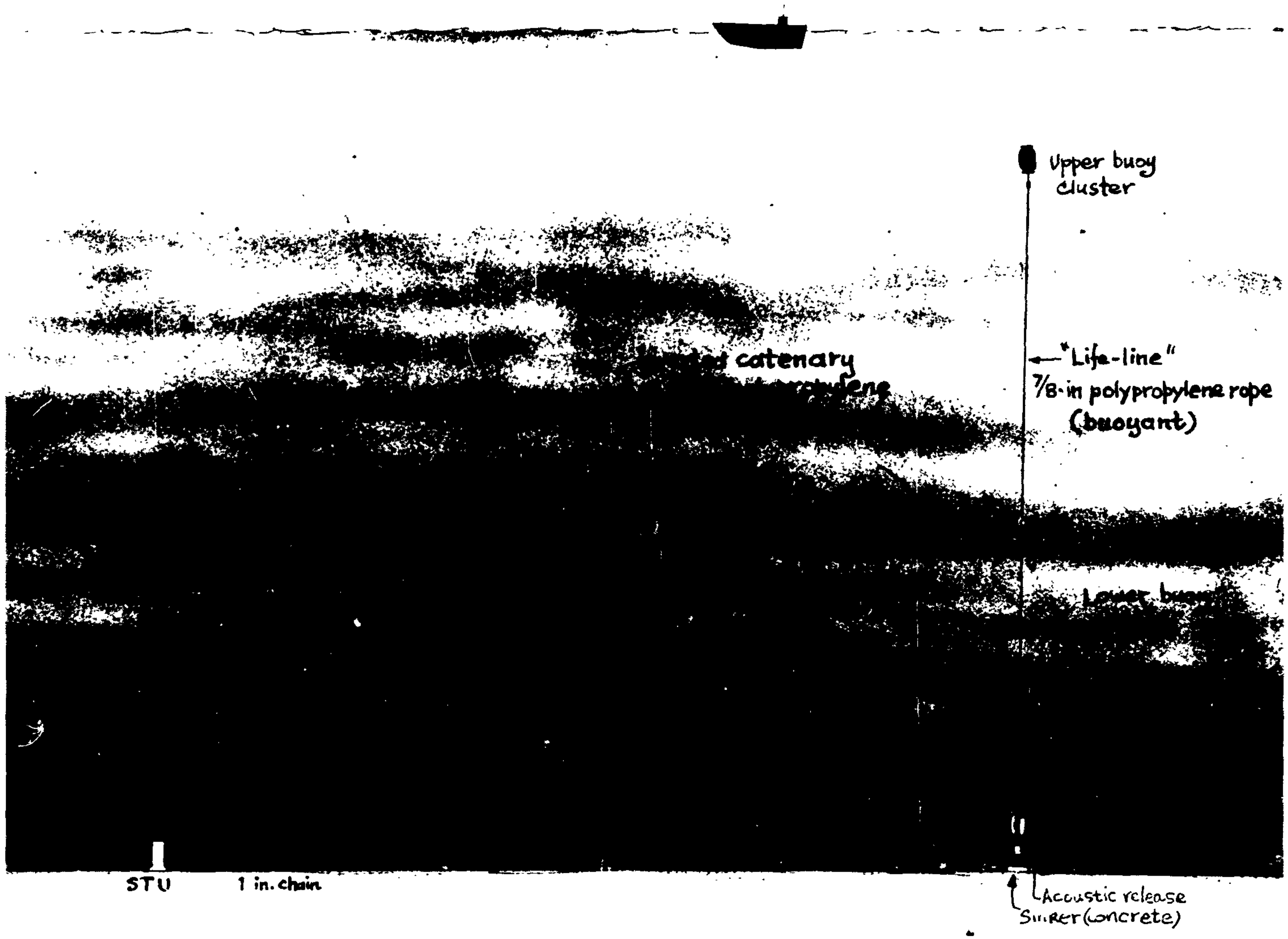

Figure 4. Schematic of STU complex.

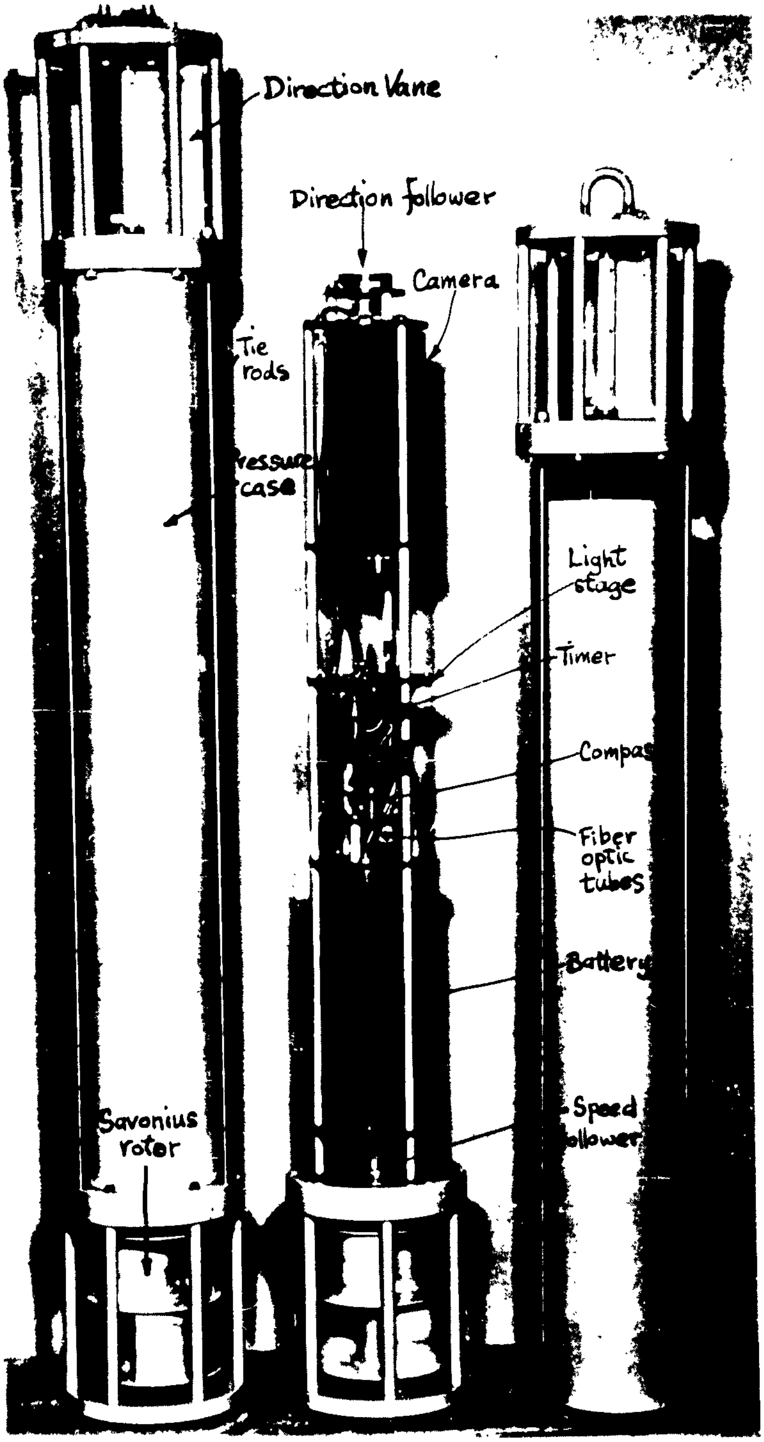

Figure 5. Recording Current Meter (WHOI).

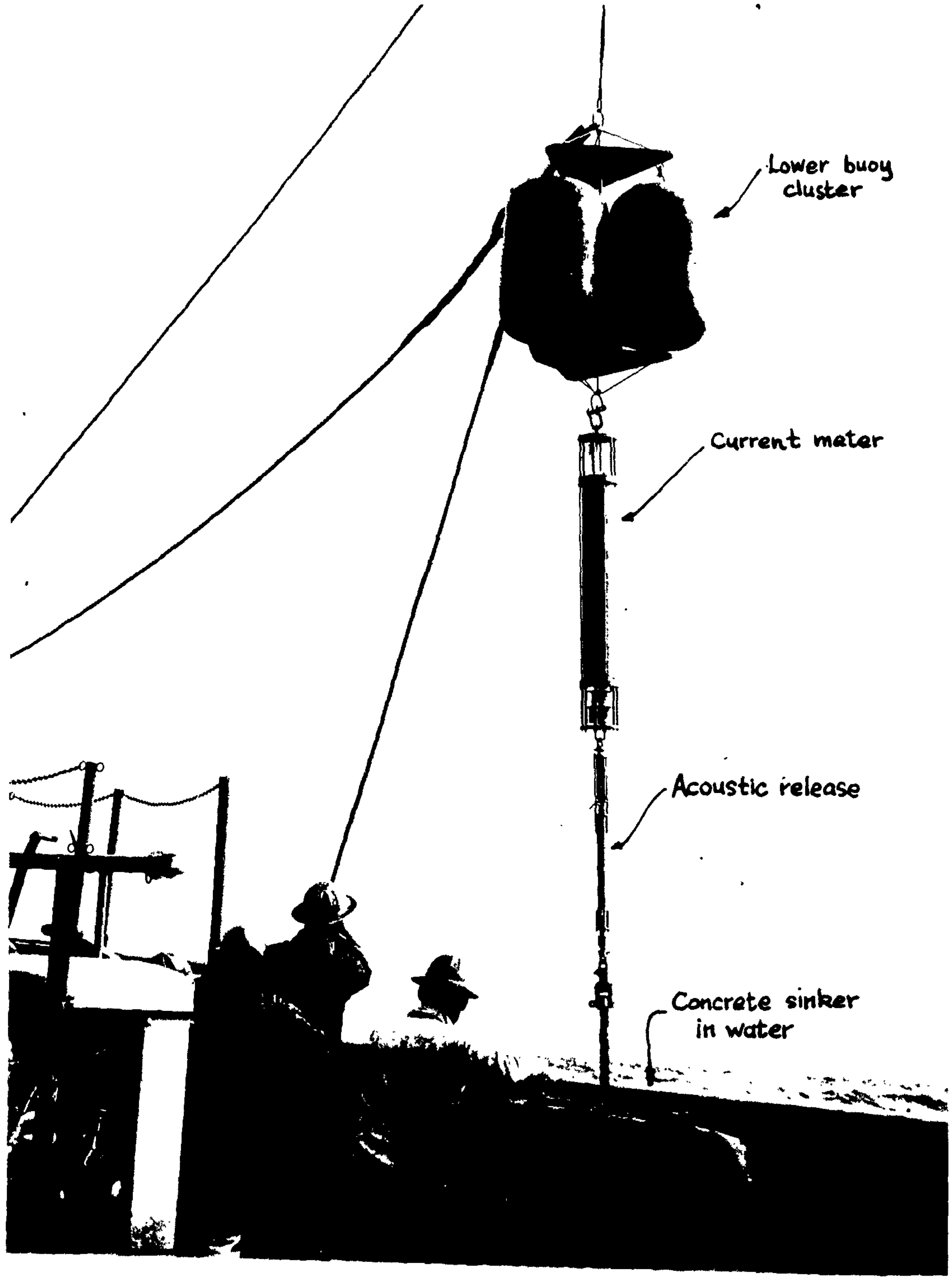

Figure 6. Assembly at bottom of life line.

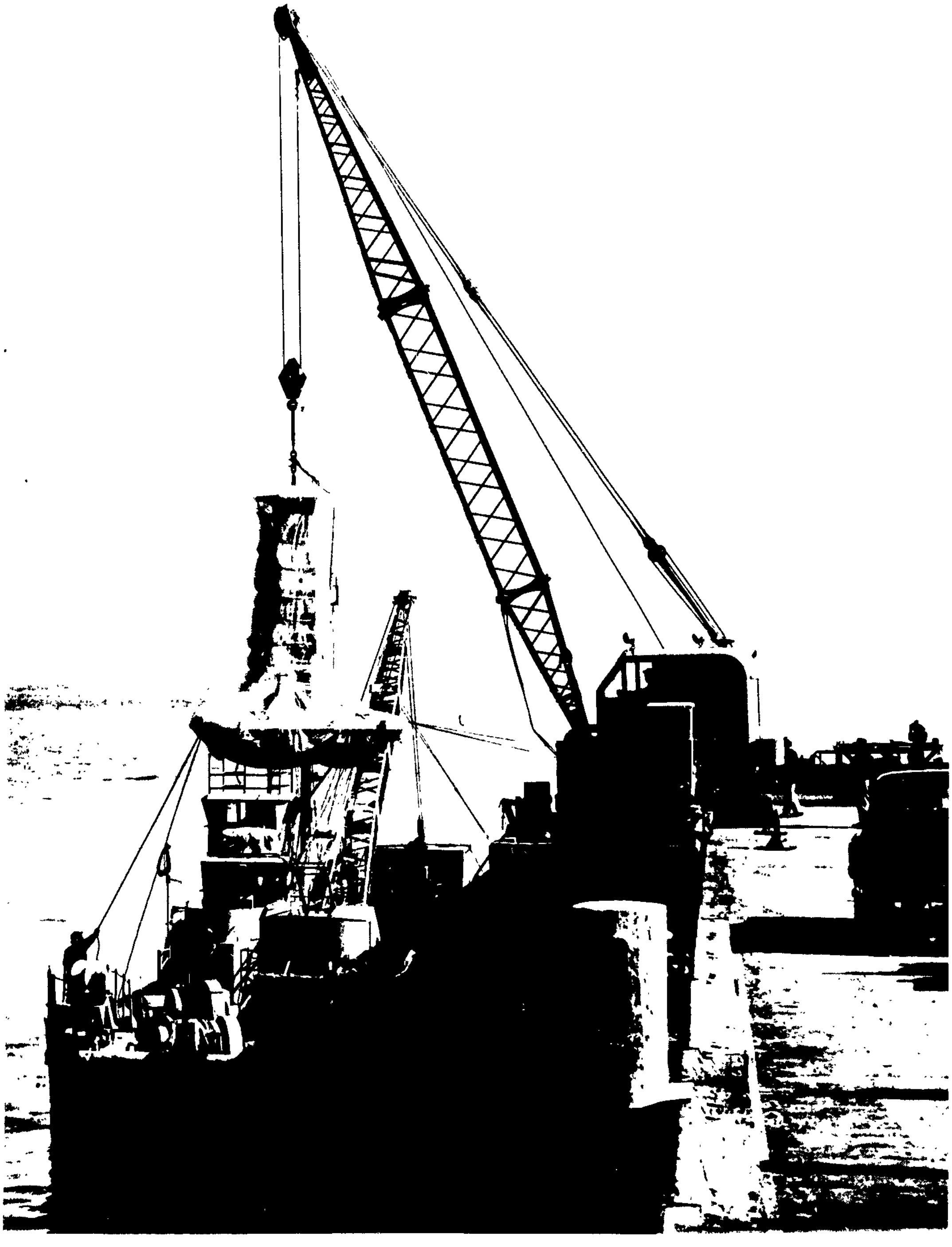

Figure 7. YFU at Santa Rosa Island - STU was temporarily unloaded to enable anchor and buoy to be placed at site.

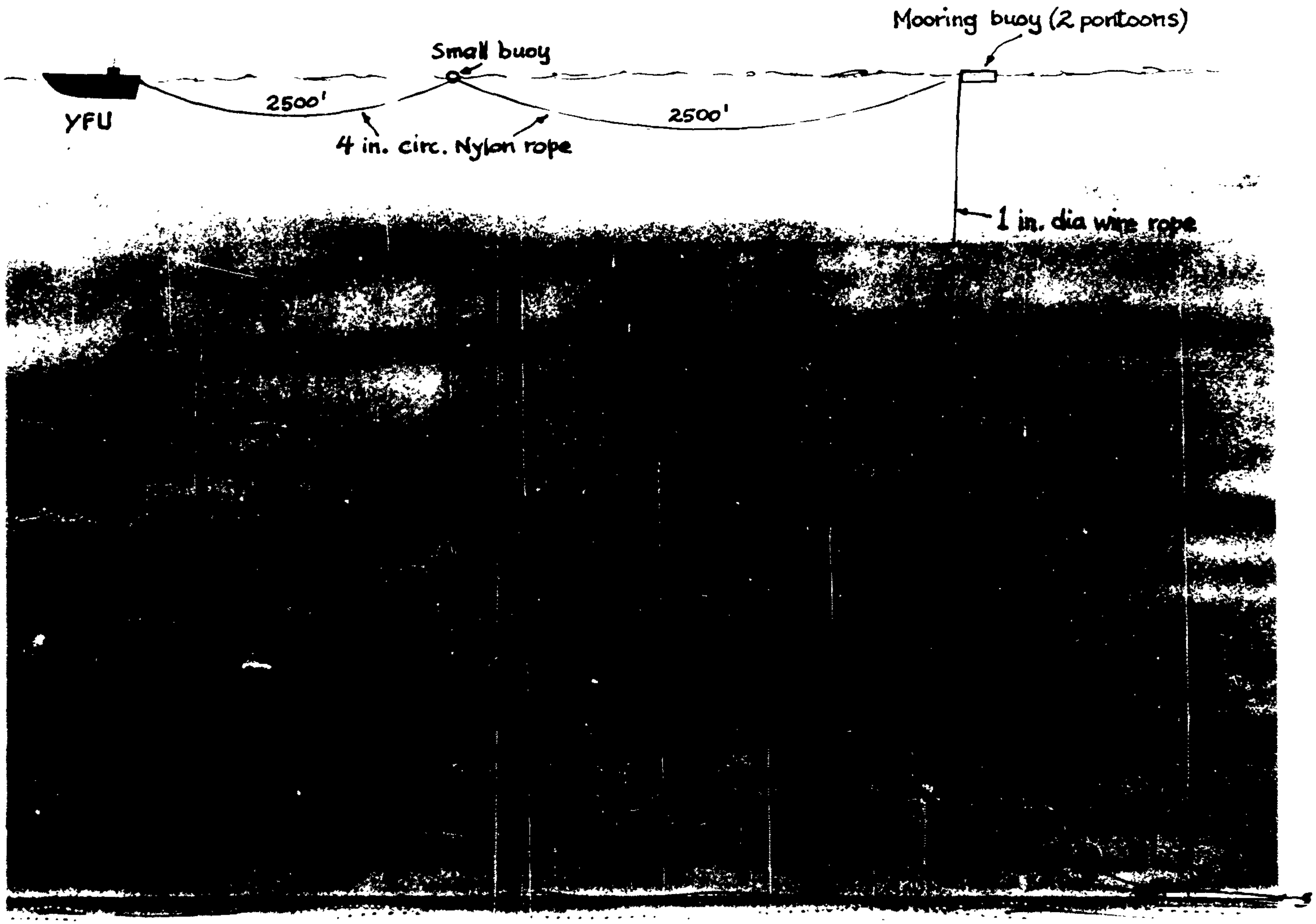

Figure 8. Temporary mooring at STU site.

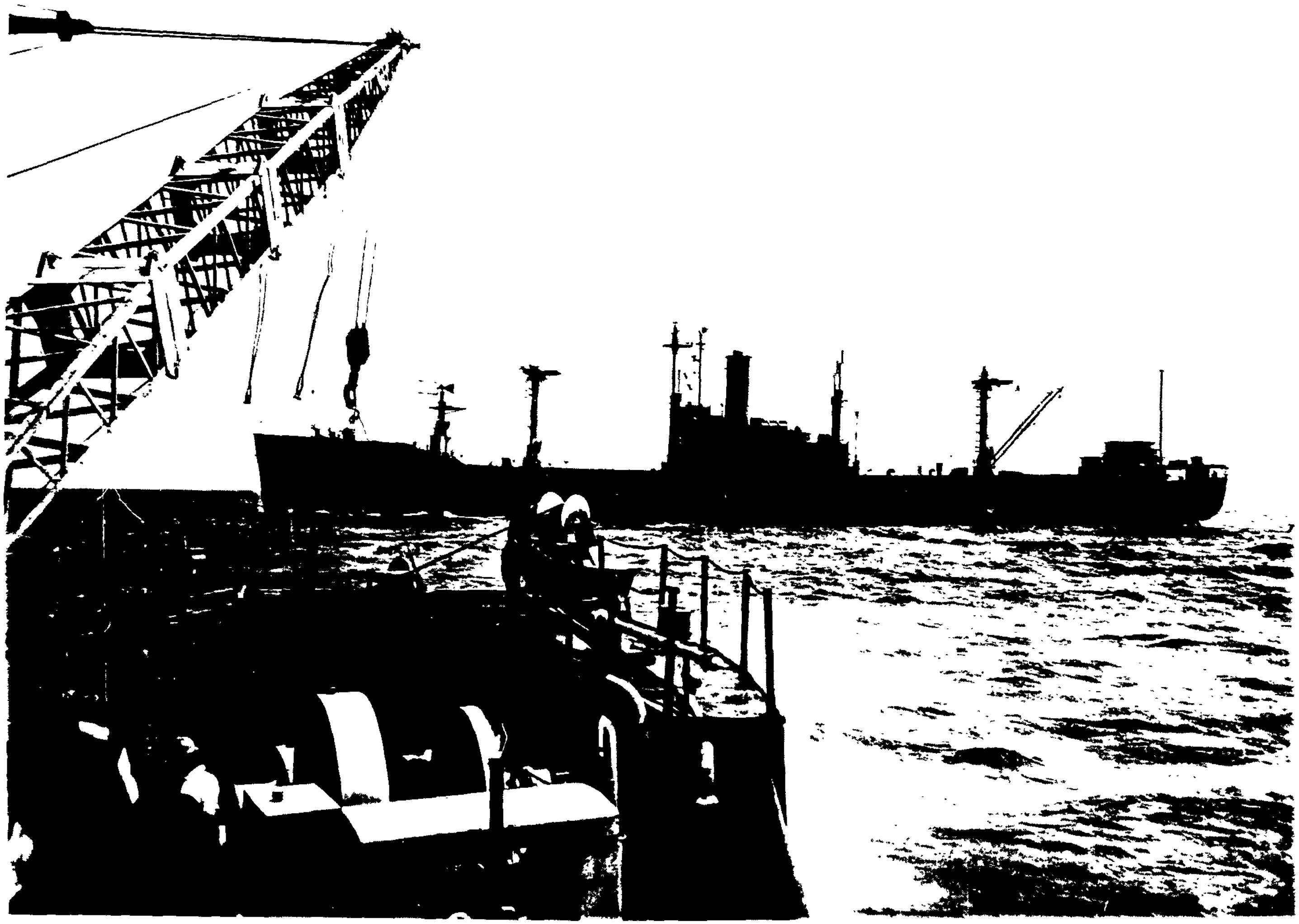

Figure 9. USNS RICHFIELD - a stable platform for locating Tellurometers.

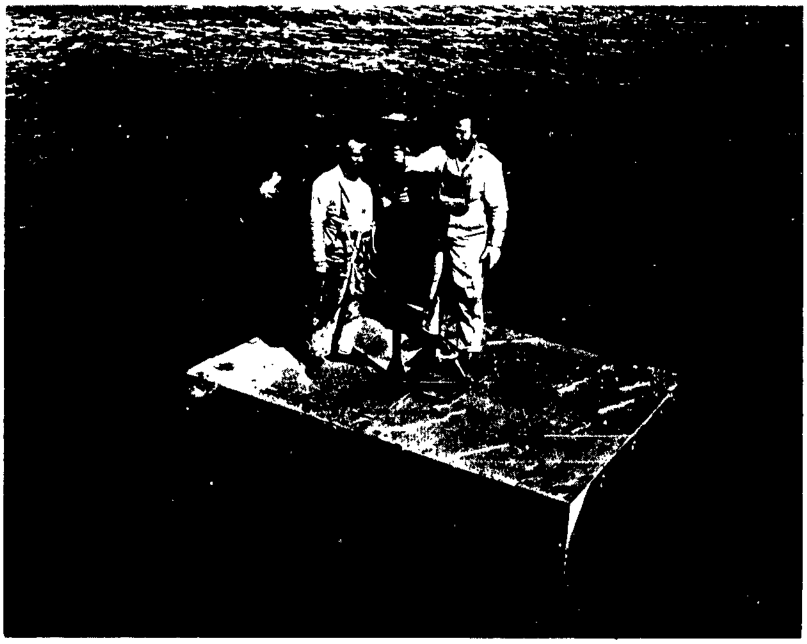

Figure 10. Temporary mooring buoy at STU site. Riggers preparing to hook up nylon mooring line for YFU.

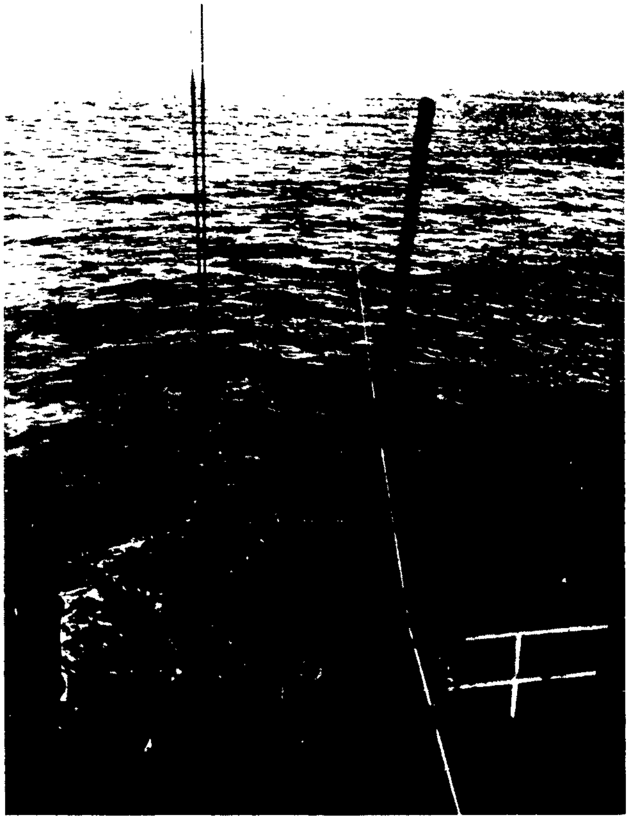

Figure 11. Nylon mooring line over stern roller of YFU. Ship's power is used to maintain tension.

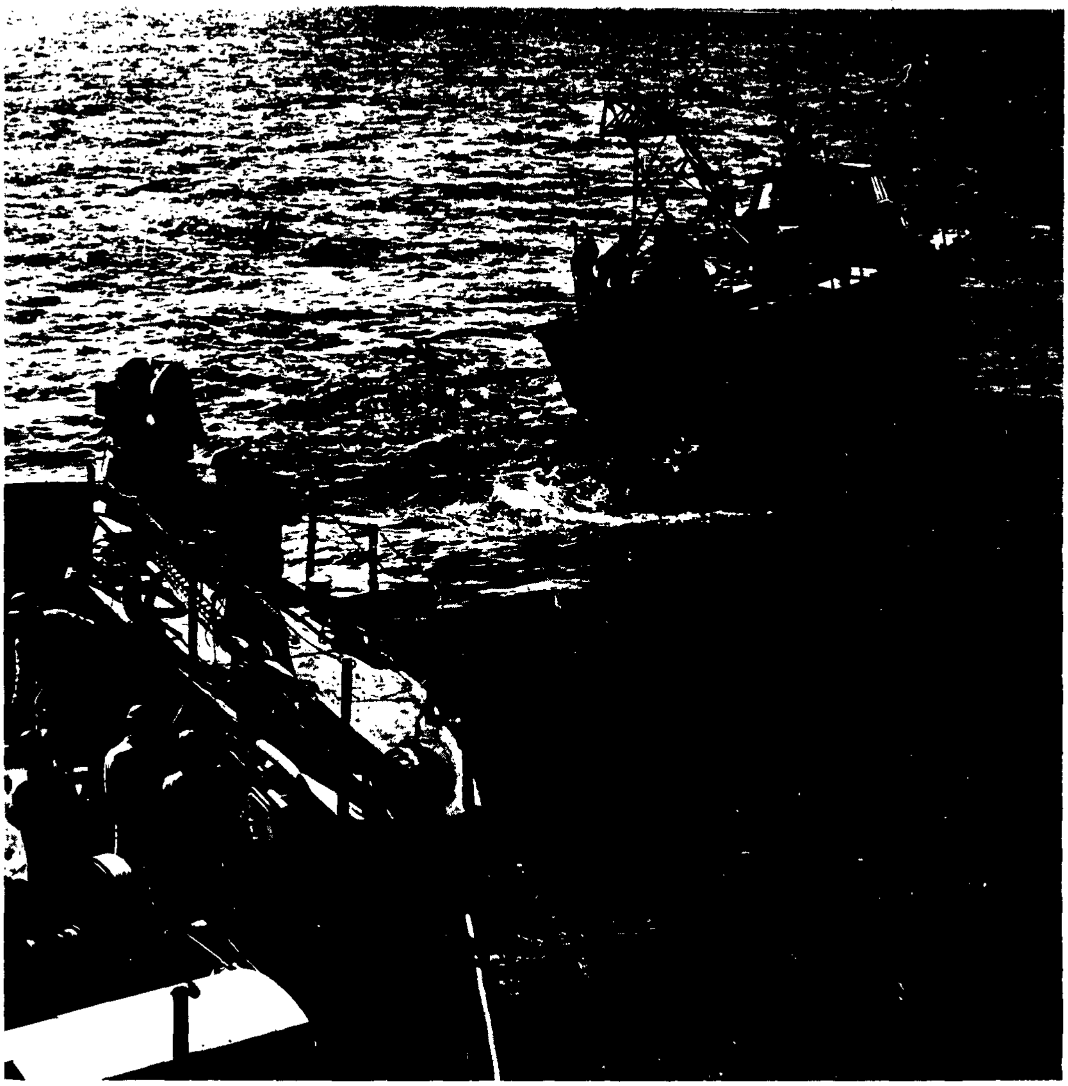

Figure 12. P.T. boat lays electrode cable and tag line from recorder mounted near base of STU.

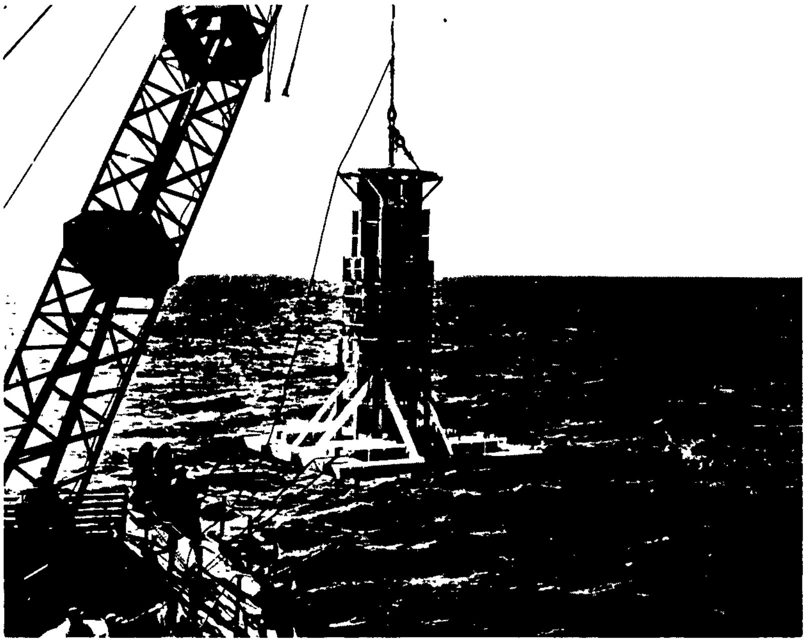

Figure 13. STU being placed over side from YFU 48.

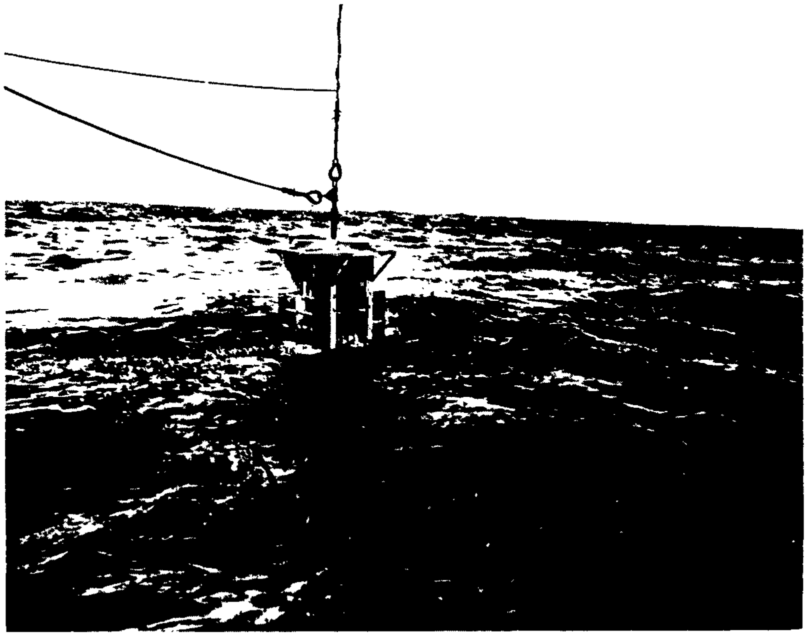

Figure 14. STU about to disappear into sea for emplacement.

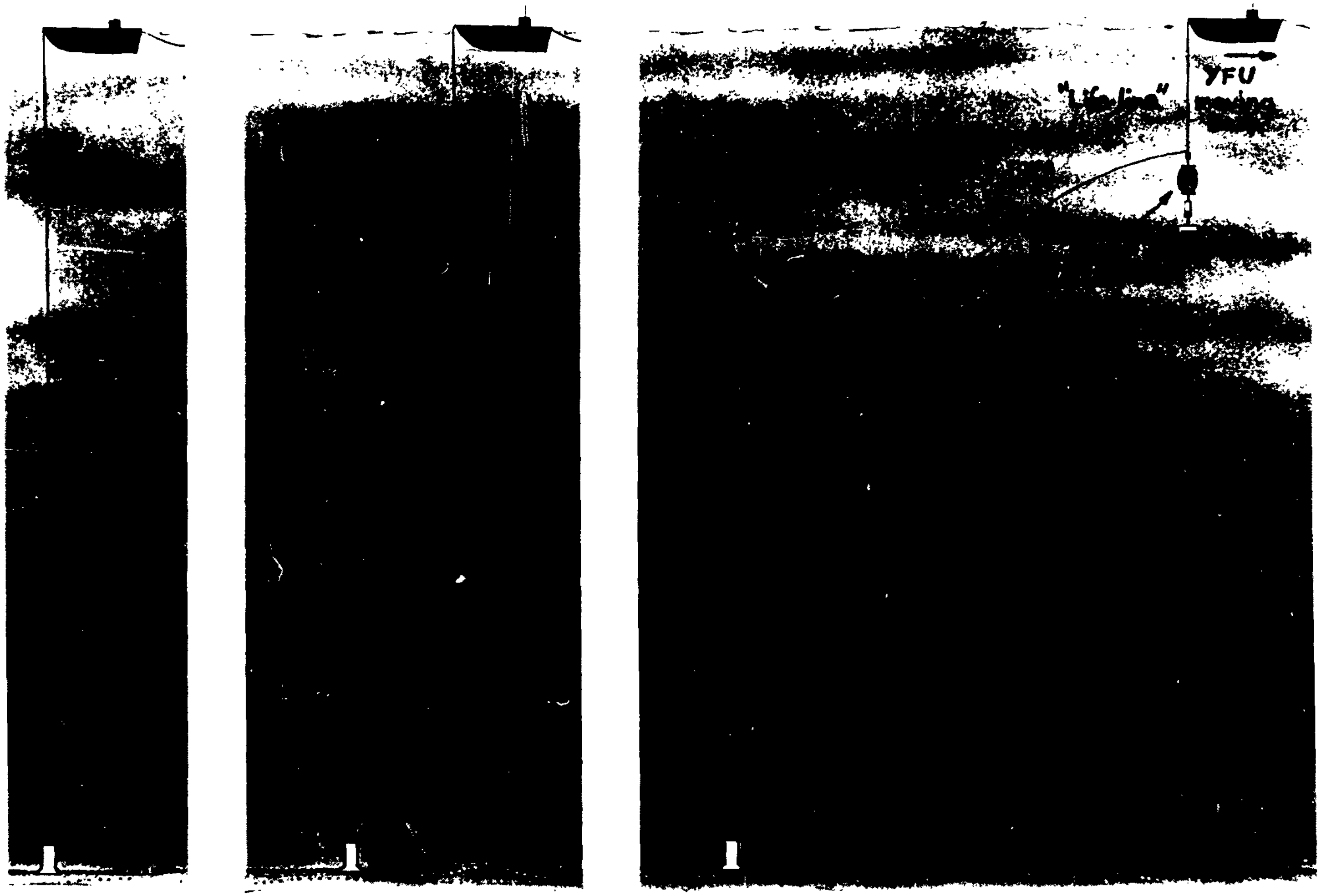

Figure 15. Step 1. Lowering STU. Step 2. Nylon and chain placed on bottom. Step 3. Forming inverted catenary.

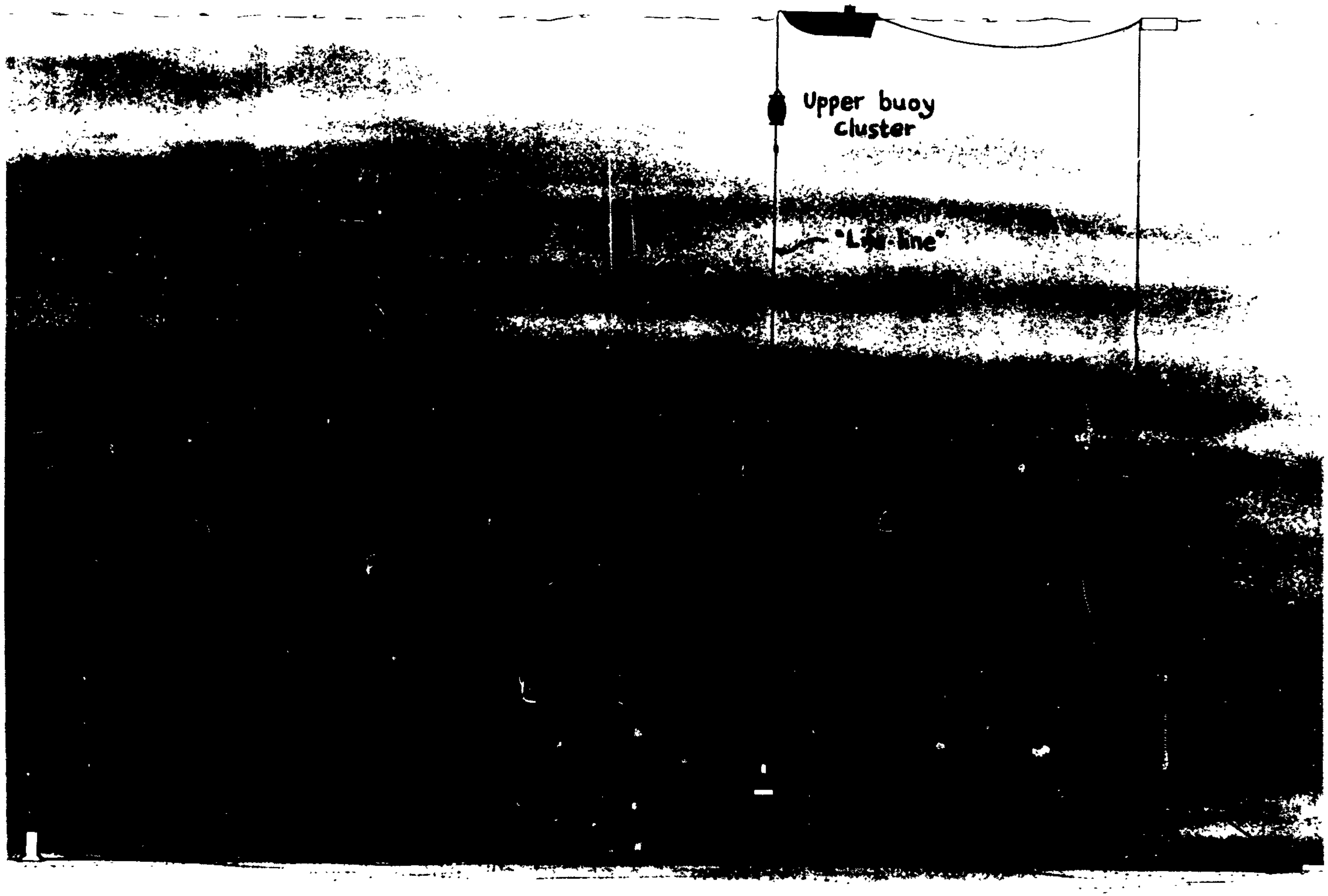

Figure 16. Step 4. Inverted catenary almost complete.

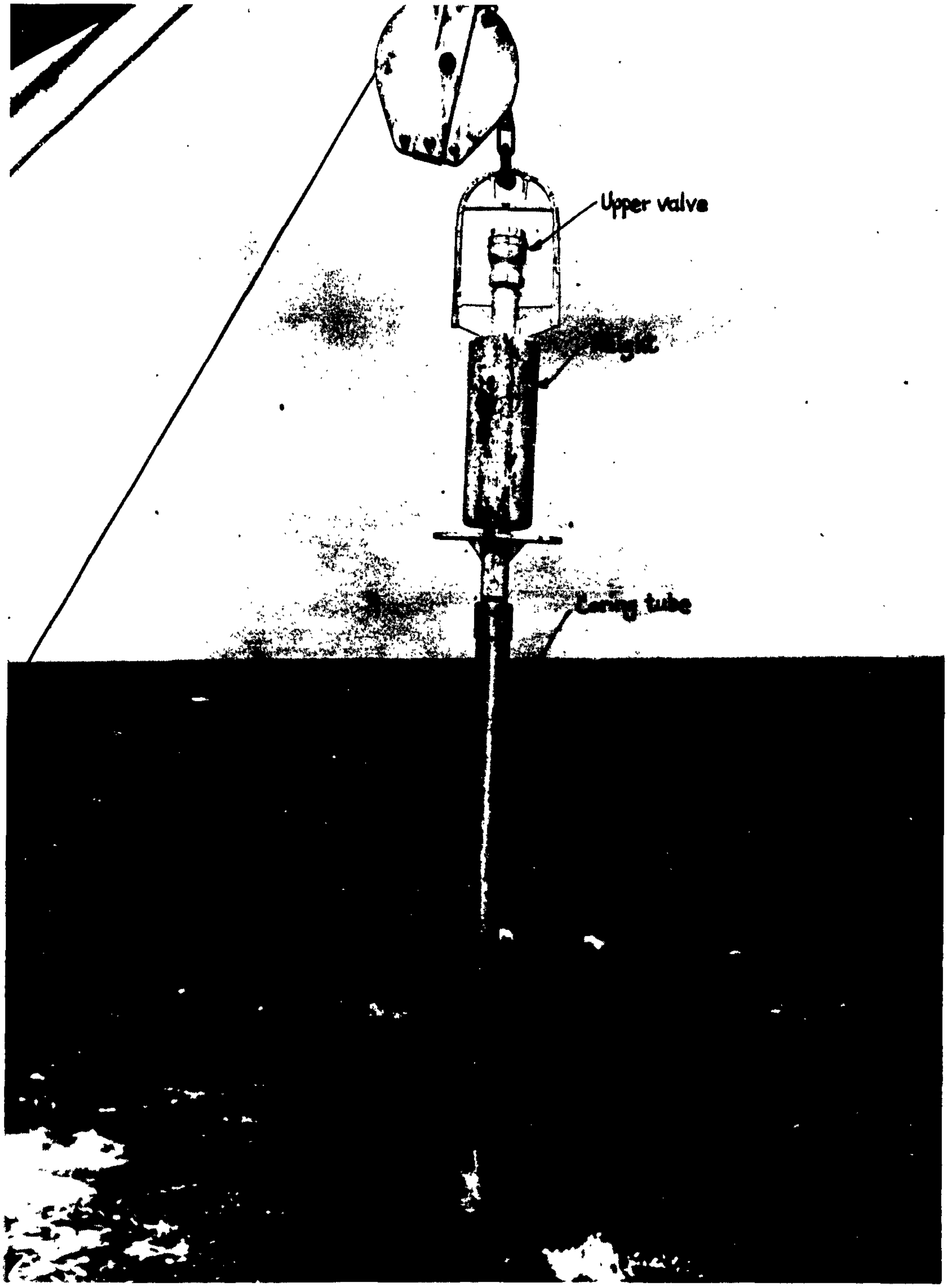

Figure 17. Gravity corer.

Figure 18. Core retrieved from 5300 ft contained in plastic liner capped at both ends for storage in a vertical position.

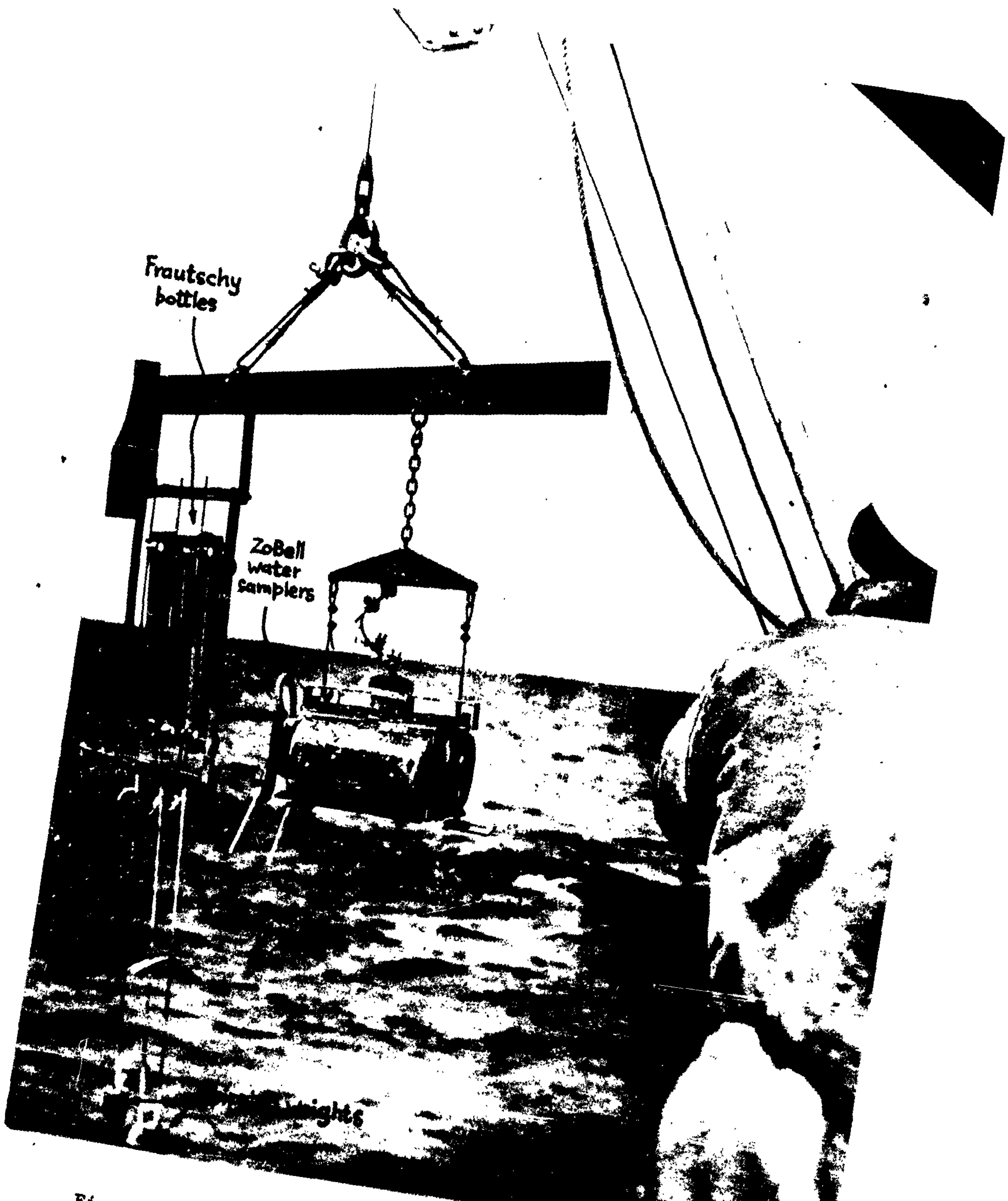

Figure 19. Sampler array for multiple sampling to conserve time.

Figure 20. NEL Mk V Deep Sea Camera - lower unit is high intensity electronic flashbulb.

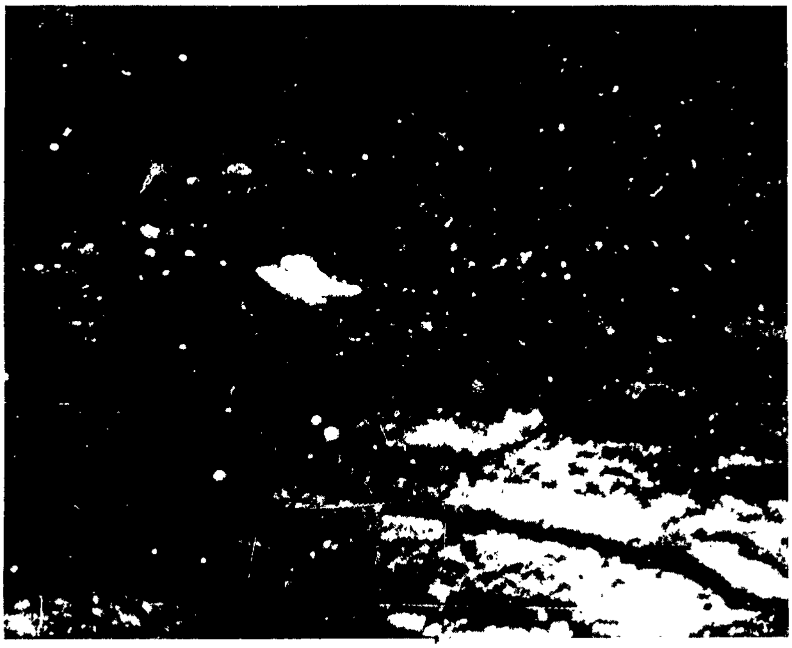

Figure 21. Sea floor photograph obtained with the NEL Mark V deep sea camera. Note the gastropod (about 2 in. long). Irregularities of the sediment surface are due to benthic burrowing organisms. The groove across the picture is caused by the support cable of the camera resting on the bottom.

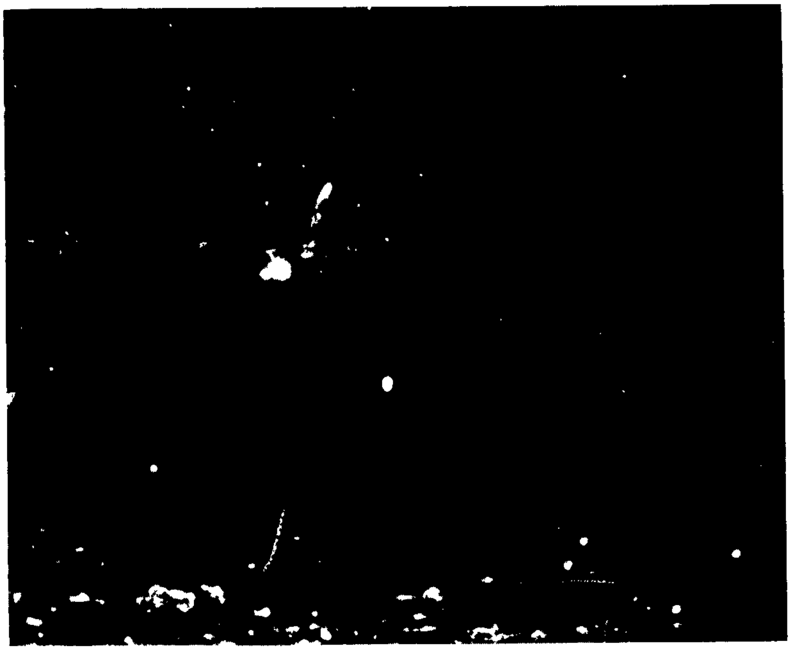

Figure 22. Sea floor photograph showing large unidentified fish (6 to 8 feet long). Note the large dorsel fin. Some luminescent organisms are present.

Figure 23. Storage drum and winding winch for polypropylene rope.

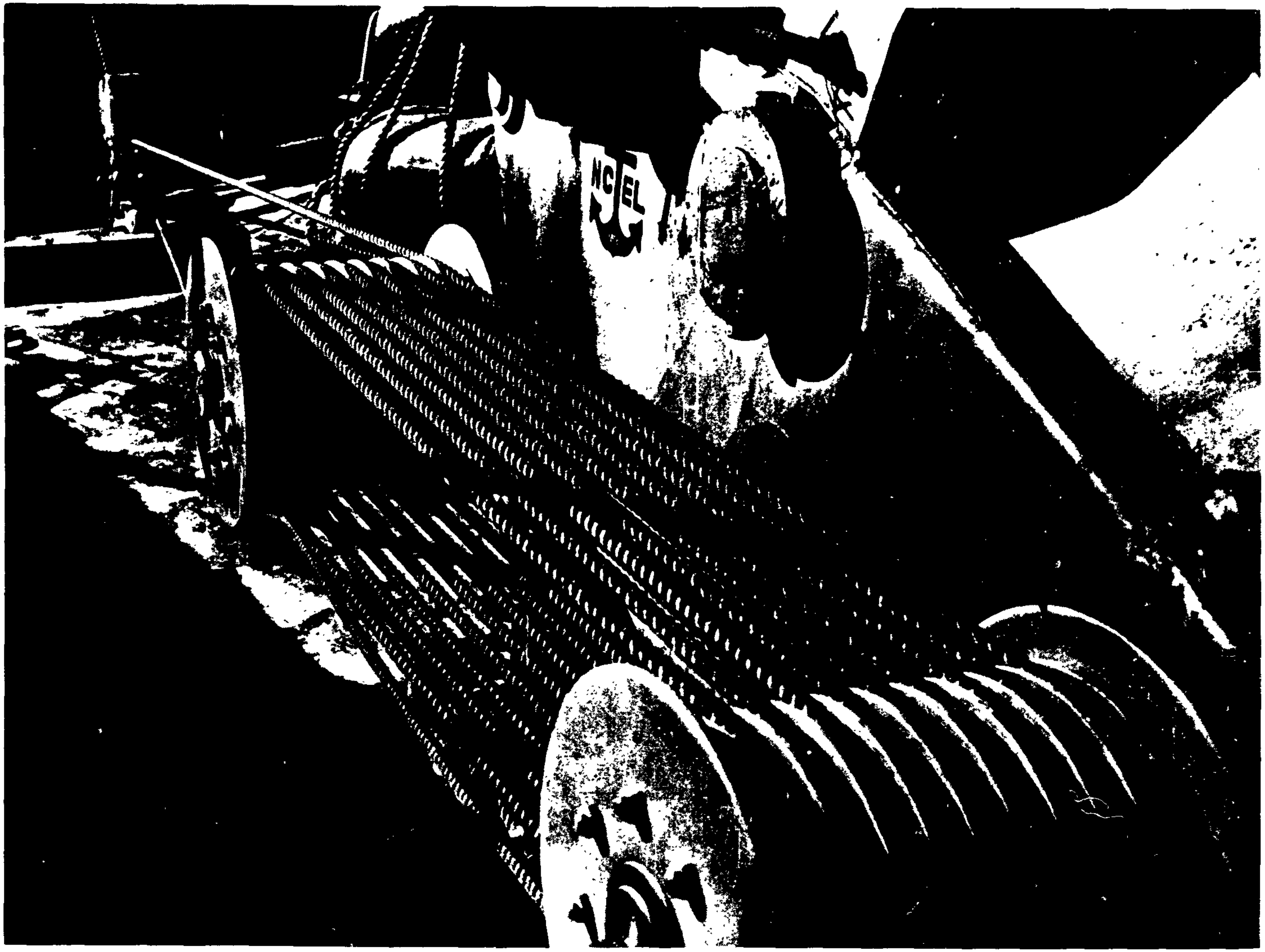

Figure 24. Close-up of winding mechanism for polypropylene rope.

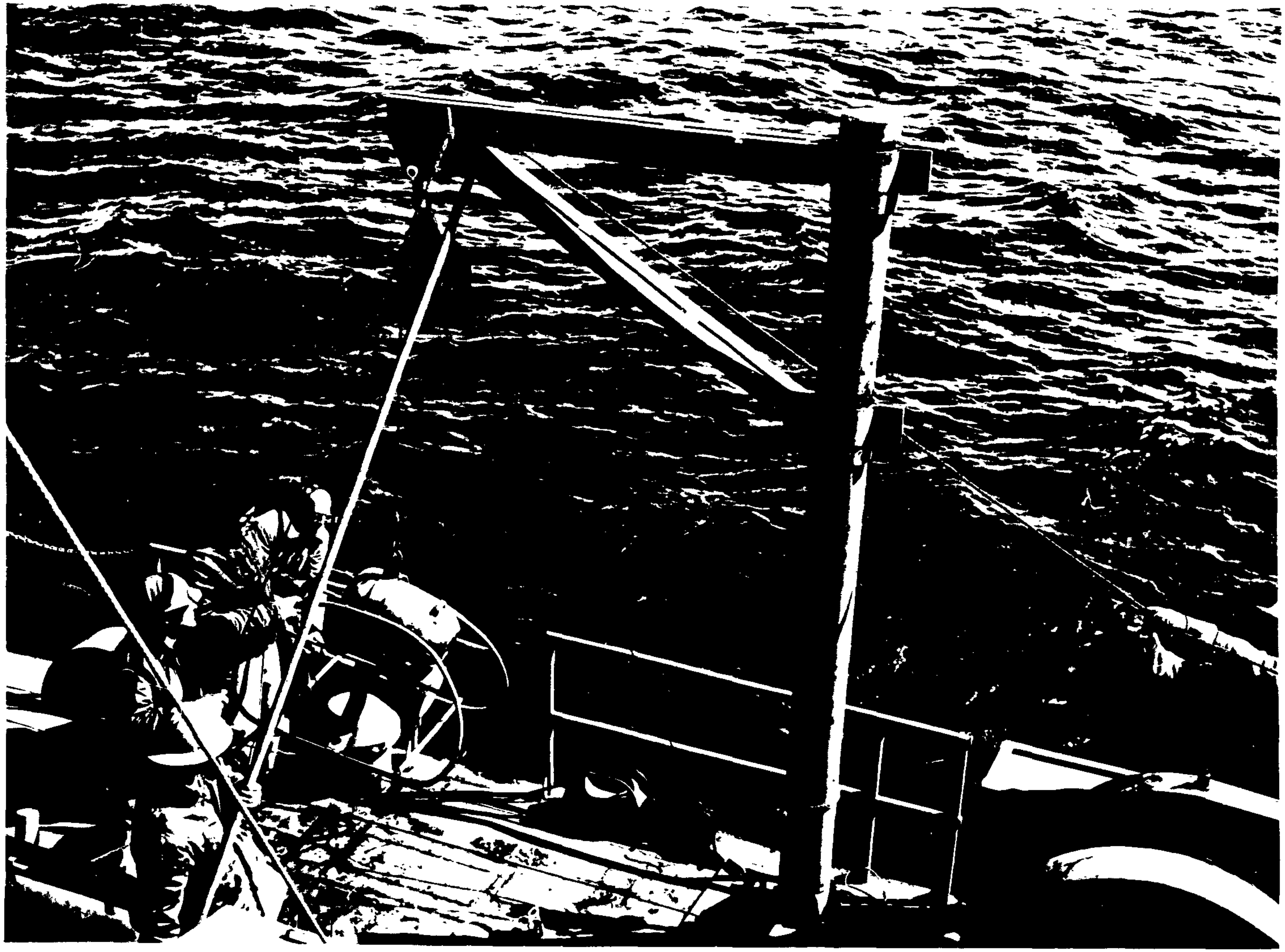

Figure 25. King post and jib used with winch at side for oceanographic casts. Deep sea camera is attached for lowering.